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A randomised controlled trial of a web-based intervention (POWeR+) with brief nurse support to manage obesity in primary care.

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Background. Intensive behavioural counselling is effective for obesity, but resource requirements severely limit widespread implementation in primary care. We aimed to estimate the effectiveness and cost-effectiveness of an internet-based behavioural intervention with brief practice nurse support.

Methods. POWeR+ is a 24 session web-based weight management intervention lasting 6 months. Adults with BMI ≥ 30 (or ≥ 28 with additional risk factors) were identified from UK GP records and sent postal invitations. Following online registration with POWeR+, patients were randomly allocated using computer generated random numbers by the website to either: 1) Control. An intervention which had previously demonstrated effectiveness: brief web-based information which minimised pressure to reduce foods, instead encouraging swaps to healthier choices and increasing fruit and vegetables, plus 6-monthly nurse weighing, or 2) POWeR+Face-to-face (POWeR+F) with face-to-face nurse-support (≤ 7 contacts/6 months), or 3) POWeR+Remote (POWeR+R) with remote nurse-support (≤ 5 emails or brief phone calls/6 months).

Findings. Weight loss averaged over 12 months (the primary outcome) was documented among 666/818 (81%) participants. Analysis was intention to treat analysis using multiple imputation for missing data. The control group lost nearly 3 Kg (baseline 104.4, 6 months 101.9, 12 months 101.7). Compared with the control group POWeR+F achieved additional weight reduction of 1.5kg averaged over 12 months (95% confidence intervals 0.6 to 2.4, $p=0.001$) and 1.3kg for POWeR+R (0.34 to 2.2, $p=0.007$). By 12 months 20.8% of the control group had maintained a clinically important 5% weight reduction, POWeR+F 29.2% (Risk ratio 1.56, 0.96 to 2.51, $p=0.070$), and POWeR+R 32.4% (1.82, 1.31 to 2.74, $p=0.004$). Health service costs of the intervention were low, and the incremental overall cost per kg weight lost compared to the control group was £18 (-129 to 195) for POWeR+F and -£25 (-268 to 157) for POWeR+R. The probability of being cost-effective at a threshold of £100/kg lost was 88% and 98% respectively. No adverse events were reported.

Interpretation. Weight loss was maintained for some individuals by promoting novel written materials with occasional brief nurse follow-up. However, more can maintain clinically important and cost-effective weight reduction with a web-based behavioural programme and brief remote follow-up.

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Background

Obesity is a major threat to public health, the prevalence is rising¹⁻³ and the vast majority of patients are managed in primary care⁴. Systematic reviews⁵, including from NICE⁴, advocate dietary and physical activity intervention supported by intensive behavioural techniques. The limited availability of high level dietetic and behavior-change expertise, nor time available for counselling and follow-up, make this challenging in the progressively resource-constrained primary care environment⁶. A review of controlled trials in primary care (but excluding those with >30% attrition at 12 months, which is common in studies of obesity) found little evidence of appropriately intensive behavioural counselling and suggested trained interventionists⁷.

An alternative to a cadre of highly trained interventionists is to use the internet to help support behaviour change. Reviews suggest that automated interactive web-interventions without human input can achieve weight loss greater than no treatment or minimal interventions, but with too many small, short-term trials in volunteer samples, arguing the need for large, pragmatic trials with at least one year follow-up and assessing cost-effectiveness^{8 9}. The trials identified by NICE mostly had expert lifestyle and behavioural input, and followed up patients intensively - on average 13 times per year during the first 12 months⁴. NICE found that estimates of cost-effectiveness were very sensitive to whether weight loss was maintained, but estimated that any intervention which cost less than £100 per kg lost if maintained in the longer term was likely to be cost effective. Automated interventions may be enhanced by human support, but while intensive support improves web-based weight management¹⁰ we are aware of no studies examining the effectiveness of the brief support by primary care staff that is likely to be both more feasible and cost-effective. A recent review identified 9 studies comparing internet support with minimal intervention, but 2 had unusual populations (University staff; lactating women), and the only study to report fewer than 10 contacts by behavioural counsellors documented less than 1.5Kg weight loss and high attrition at 12 months with only 49% of individuals followed-up¹¹.

Our objective was to perform a parallel group pragmatic randomised primary care trial to estimate the effectiveness and cost-effectiveness of a web-based behavioural weight management intervention (POWeR+) with either brief face-to-face nurse support or brief remote nurse support for obese patients managed in UK primary care. To minimise drop-out we chose an active control group promoting healthy eating that had previously been shown to result in modest weight loss (2%) compared to a generic advice booklet¹². The primary outcome was weight reduction averaged over 12 months and a secondary weight outcome the proportion achieving a clinically important 5% reduction in weight.

Research methods

Participants.

Practices in Central and South England (around Southampton and Oxford) identified participants from their routine electronic records. Up to 100 patients from each practice were randomly chosen, and invited to a screening appointment. Patients could also be referred opportunistically from routine practice appointments.

Inclusion criteria.

Patients with BMI ≥ 30 kg/m² (or ≥ 28 kg/m² with hypertension or hypercholesterolaemia) documented in the GP case records⁴ were eligible.

Exclusion criteria: major mental problems e.g. psychosis (difficulty completing outcomes); too ill or unable to change diet (e.g. severe LVF); pregnancy; breast feeding; or perceived inability to walk 100 metres (physical activity difficult); another member of the household taking part, no regular access to the internet.

The POWeR+ web-based intervention

POWeR+ is a theory and evidence-based intervention to teach patients self-regulation and cognitive-behavioural techniques to form sustainable eating and physical activity habits for long-term weight management in a series of 24 web-based sessions designed to be used over 6 months with novel content, links to external content and email reminders. Patients initially choose either a low calorie eating plan or a low carbohydrate eating plan, but could change plans at any stage if they wished. (see Appendix 1 for full details).

Randomisation in main trial, informed consent.

During the screening appointment, informed written consent was taken. Participants were given details of how to login and register, whereupon participants were presented with baseline questionnaires, upon completion of which they were automatically randomised by the website using computer generated random numbers to one of three intervention arms:

1) Control group: evidence-based dietetic advice and 6 monthly nurse follow-up. Participants were taken to a set of 2 printable web-based pages with brief structured advice. This intervention was active since it was intended to help weight-loss: the materials were developed by the Institute of Food Research to provide attractive strategies to minimise the pressure to cut down favourite foods, but instead to swap less healthy foods for healthier choices (healthy foods swap sheet), or to increase fruit and vegetables (we used the NHS 5-a-day sheet). Our previous trial documented 1.2 Kg weight loss among patients with hypertension when compared with a generic advice booklet¹¹. To enhance retention participants were informed that this intervention had supported weight loss. Nurses arranged brief follow-up (5-10 minute

appointments) with sufficient time to measure weight at 6 months and 12 months, but not to provide explicit counselling.

2) *POWeR+F: Web-based intervention and face-to-face nurse support.* The rationale for this intervention was to provide automated behavioural counselling, with just three scheduled (and four optional) face-to-face nurse support sessions, thus requiring substantially less health professional skill and time than the evidence based lifestyle interventions documented in the NICE review⁴ and hence much easier to implement in the NHS. In addition to 6 monthly weighing, as in the control group, participants had 3 scheduled face-to-face appointments in the first 3 months and then up to 4 more during a further 3 months if needed (i.e. 6 months in total). Weight gain on two consecutive logins triggered an automated email to the nurse advising that the patient required further support, or patients could request additional support.

3) *POWeR+R: Web intervention and remote support.* The rationale here was to test whether even briefer professional support for the web intervention could be effective. Patients could access the same web-based intervention as in the face-to-face group. In addition to 6 monthly weighing, as in the control group, participants had 3 scheduled phone or email contacts and up to 2 optional phone/email contacts in the first 6 months (triggered by weight gain or patient request as in the face to face group).

Changes to the protocol.

The Trial Steering Committee (TSC) advised an increased the sample size to allow for clustering which required an extension to the planned recruitment period. To avoid losing data a repeated measures ANOVA for the principal continuous outcome (i.e. weight) was changed to mixed multivariable regression modelling. Actiheart monitors were planned for a randomised subset, but organising this at a time of intensive final follow-up became too difficult. Piloting suggested that intensive follow-up for anything but the primary outcome would increase drop-out, so efforts concentrated on weight. The final analysis plan, matching the clinical rationale for our original sample size, included a secondary weight outcome - the proportion maintaining 5% weight loss. This is very important clinically^{13 14} and facilitated direct comparison with a previous UK primary care trial¹⁵ which published after our study commenced.

Outcome measures

Primary outcome (specified in the funding protocol): Weight loss averaged over a 12 month period, measured lightly clothed, without shoes, where possible at the same time each day, using automated Tanita digital scales.

Secondary weight outcome: maintenance of 5% weight loss.

Other outcomes. There was no explicit measurement of the ‘work’ of participants when, but we report health service resource use, usage of the website (pages accessed and time taken, recorded automatically by the website), and how enabled patients felt (using the modified Patient enablement instrument¹⁶), and the additional activities participants used to help lose weight. A range of other secondary measures were also

documented (waist measurement, blood pressure, HBA1C, liver function tests; self-report measures of physical activity, diet, see Appendix 4 for detail).

Outcomes/data collection (at baseline and unless specified at 6 and 12 months). Participants had appointments for weight measurement with the practice nurse at baseline and 6 months, and at 12 months an appointment or home visit by a nurse researcher blinded to group. Where a blinded weight measurement could not be obtained we used practice nurses' recorded weights, and where that was not possible we used participants' reported weight. For self-report measures there were three emails prompting online completion followed by a postal version of the questionnaire.

Sample size.

We compared each of the intervention groups primarily with control but also potentially with each other so allowed for $\alpha=0.017$ (i.e. $0.05/3$). For the primary outcome (weight) we estimated that a standardised effect size of 0.33 (equivalent to 2-3 kg difference assuming an SD of change of 6.5-7.5 kg^{17 18}) and 80% power required 174 patients per group with complete data, or 654 patients in total allowing for 20% loss to follow-up. Following liaison with both the funder (HTA) and the TSC the power calculation was revised to allow for modest clustering at practice level if significant clustering was found. We assumed recruitment of 18 patients per practice to achieve 15 patients at follow-up, of whom roughly 5-6 would be in each of the two intervention groups at follow-up. Assuming 5 per group in each practice for an ICC (intra-cluster correlation) of 0.05 i.e. a design effect 1.2 ($1 + ((5-1) \times 0.05)$) this resulted in a minimum of $654 \times 1.2 = 785$ patients.

Statistical analysis.

The primary analysis. Mixed multivariate regression models were chosen to enable data to be used from anyone who had 6 months or 12 months data. We modelled the risk ratios compared with the control group for the number achieving 5% weight loss. All regression models controlled for weight at baseline, sex, age, smoking, diabetes, medications (including Orlistat used at baseline), any comorbidities, deprivation (IMD2010) and any clustering by practice. No interim analyses were undertaken as per the approved study protocol.

Missing data. Loss to follow-up was fairly similar between arms which reduces the potential impact of data not following the missing at random assumption. Nevertheless, intention to treat analysis used both measured and reported weights in a multiply-imputed data set (based on 50 replications). Secondary analyses were of complete cases, and also just using measured weights – both of which analyses documented slightly larger effect sizes.

Subgroup analyses: We explored whether there was significant effect modification in subgroups using interaction terms in the models. Key subgroups identified in advance were: baseline waist measurement (high or very high waist vs low waist: men high 94cm, very high 102cm; women high 80cm, very high 88cm), and the presence of the metabolic syndrome (syndrome vs no syndrome). The metabolic syndrome¹⁹ was defined as 3 out of 5 of elevated waist circumference (<94 cm for men, 80 for women), TG

≥ 1.7 mmol/l, reduced HDL-cholesterol (< 1.00 mmol/L in males < 1.3 mmol/l in females) BP (SPB > 130 or diastolic > 85 , or treatment of high BP) elevated fasting glucose ≥ 5.6 mmol/l.²⁰ We also explored outcomes according to the type of diet chosen by patients.

Economic evaluation

Health service resource use data (see Appendix 2 for more detail) were collected through case notes review covering medication, primary care visits, outpatient consultant, A+E and hospital admissions associated with obesity (the management of obesity, and conditions affected by obesity such as cardiovascular disease, control of asthma, and musculoskeletal problems (hip, back and knee)). Outcomes were measured as incremental costs per Kg weight loss. We have applied multiple imputation for missing values and applied bootstrapping to the imputed data to produce confidence intervals for the cost-effectiveness analyses.

Trial registration and ethics

The trial was registered on 16/3/12 as an International Standard Randomised Controlled Trial (ISRCTN21244703) and ethics approval given by NRES Committee South Central Southampton B First MREC (approval date 19/12/2011, reference: 11/SC/0455). A £10 gift voucher was sent out with the 12 month appointment notification letter as a thank you for participation irrespective of whether an appointment was made.

Role of the funding source

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Results

818 eligible individuals from 56 practices were randomised from January 2013 to March 2014. Of these, 407 had a weight recorded at the 6 month follow up and 666 had a weight recorded at 12 months. Of the 666, 510 (76.7%) were blinded weights, 28 (4.2%) unblinded weights and 128 (19.2%) reported weights. The number with reported weights were similar in each group (Control n=40, POWeR+F n=48, POWeR+R n=40). Table 1 shows the baseline characteristics of the groups, which were mostly well balanced. The practice intra-cluster correlation (icc) for weight in the repeated measures analysis was 0.01 (95% confidence intervals 0.003 to 0.09) when controlling for baseline weight.

Intervention receipt.

Of the 539 participants randomised to the POWER+ intervention groups, 524 started the first session and 404 completed all 3 core sessions (196 of the remote support group and 208 of the Face-to-face support group). Participants completed an average of 10.97 (SD=12.65) weight and goal reviews (range 0-52); the average was 10.16 (SD=11.92) in the Face-to-face group and 11.85 (SD=13.38) in the Remote support group. The median number of nurse contacts was 4 (range 0 to 7) in both intervention groups, with a median of 2 face to face, 1 phone and 1 email contact in the POWeR+F group, and a median of 1 phone call and 3 emails in the POWeR+R group. There was around 2-2.5 kg difference in weight reduction for those who completed more than the first basic stage of the Programme.

Outcomes

Mean weight reduction: The active control group maintained a weight loss of nearly 3 kg over 12 months (baseline 104.4 Kg (n=279), 6 months 101.9 Kg (n=136), 12 months 101.7 Kg (n=227) (Table 2). The primary imputed analysis (Table 3) documented that compared to the control group the face to face support group achieved an estimated additional 1.5 kg reduction averaged over the 12 months period (-2.4 to -0.6, p=0.001) and the remote group an additional 1.3kg reduction (-2.3 to -0.3, p=0.005). A secondary analysis of just the complete cases over 12 months documented greater weight reduction compared to the control group: Face-to-face -1.78 kg (-2.8 to -0.8), Remote -1.6 kg (-2.6 to -0.6) (see Tables 8 and 9, Appendix 3).

Clinically important weight maintenance: By 12 months using data from complete cases 18.5% (42/227) of the control group had maintained a 5% or more reduction in weight, POWeR+Face-to-face 28.1% (62/221) and POWeR+Remote 31.7% (69/218). The imputed estimates were respectively 20.8%, 29.2%, and 32.4% (Table 4).

NHS resource use and other activities.

753 casenotes were reviewed from the GP electronic records for 12 months after recruitment. The mean intervention costs per person using the services were low (£22 for POWeR+F and POWeR+R £12), or for all participants in each group £17 and £9 respectively. Adding the estimated cost of the web raised

these to £18 and £10 respectively. Bigger differences in costs were found in estimating overall NHS resource use related to obesity (see Table 7b). If bootstrapping is used the estimate of the differences in costs compared with the control group for POWeR+ Face-to Face is £23 (-105 to 152) and for POWeR+Remote -£36 (-154 to 81). None of these differences were statistically significant. The estimated incremental overall NHS cost per kg weight loss was £18 (-129 to 195) for POWeR+F, and -£25 (-268 to 157) for POWeR+R. i.e. POWeR+R dominated the control group since it was more effective and cost less (see Table 5). The cost-effectiveness acceptability curves put the probability of being cost effective at well over 80% for both interventions (88% and 98% respectively) compared with the control group (see Appendix 2 for more details).

For those returning the final questionnaire almost half the people in the control group (47.1%; 64/136) were doing something else to help lose weight as opposed to 37.2% (51/137) in the Face-to-Face group and only 26.7% (40/150) in the Remote group (Table 6). Participants also felt more enabled to manage their weight problem in the POWeR+ groups (Table 6).

Subgroups

There was some evidence of a lesser effect of the POWeR+F group at 6 months among participants with the metabolic syndrome, but no significant impact of type of diet chosen (see Appendix 3 for more detail).

Secondary outcomes

Due to the priority to obtain follow-up for weights, and the clear feedback from piloting that pressurising participants to have blood taken was off-putting, achieving high follow-up for blood samples was necessarily a secondary priority for the trial team, and so a minority of participants had follow-up blood measurements. As a result, even though estimates use multiple imputation, the results for blood samples must be interpreted cautiously. What results are available suggest generally positive directions of outcomes in the POWeR+ groups, albeit mostly not statistically significant (raised HDL cholesterol, lower AST and ALT, lower HbA1C; see Appendix 4 tables 10 to 12). The low completion rate for EQ5D makes this data less reliable, so the interpretation of the direction of change of EQ5D is difficult to interpret, particularly as the estimate of the direction of change varies depending on whether baseline values are controlled for (tables 17 and 18).

Fat mass and blood pressure were recorded in the majority of participants at follow-up (in both cases more than 450 individuals) and although there were no consistent changes in blood pressure, fat mass reduced slightly in both POWeR+ groups (Appendix 4 table 13).

Harms. No harms were reported during the study

Table 1. Baseline characteristics*

	Control group: Brief verbal and online healthy eating advice	POWeR+ Face-to-face (Access to website and brief face to face support)	POWeR+ remote: (Access to website and brief remote support)
Female (n) (%)	185/279 (66.31%)	175/269 (65.06%)	160/269 (59.48%)
Age (y)	52.69 (13.25)	53.70 (13.21)	54.74 (12.95)
Smoker (n) (%)	24/279 (8.6%)	21/269 (7.81%)	25/269 (9.29%)
Diabetes (n) (%)	48/279 (17.20%)	46/268 (17.16%)	42/270 (15.56%)
Orlistat use (n) (%)	3/270 (1.11%)	5/262 (1.91%)	5/266 (1.88%)
Comorbid condition (n) (%)	48/281 (17.08%)	55/269 (20.45%)	55/272 (20.22%)
Deprivation score (Index of Material Deprivation score 2010)	14.32 (10.45)	13.73 (10.28)	13.29 (10.17)
Weight (kg)	104.38 (21.11)	102.40 (16.87)	102.93 (18.26)
Body Mass Index (kg/m ²)	37.10 (5.97)	36.66 (5.36)	36.28 (5.65)

*Mean (S.D.) unless indicated

Table 2. Crude mean weights for complete cases at baseline, 6 and 12 months

	Mean weight in kg (s.d.)		
	Baseline	6 months	12 months
Control group: Brief online and verbal healthy eating advice	104.38 (21.11) n=279	101.91 (19.35) n=136	101.73 (19.57) n=227
POWeR+Face-to-face (Access to website and face to face support)	102.40 (16.87) n=269	97.55 (15.99) n=148	98.56 (15.95) n=221
POWeR+Remote: (Access to website and brief remote support)	102.93 (18.26) n=270	98.30 (18.34) n=155	99.72 (18.88) n=218

Table 3. Imputed data based on 50 imputations – difference in weight loss (kg) compared to control group

	Difference in weight loss compared to the control group (95% confidence intervals)		
	6 months	12 months	Over study period (repeated measures)
Face-to-face	-2.54 (-3.66, -1.42; p<0.001)	-0.37 (-1.66, 0.92; p=0.566)	-1.49 (-2.41, -0.58; p=0.001)
Remote	-1.97 (-3.18, -0.76; p=0.002)	-0.58 (-1.88, 0.72; p=0.375)	-1.27 (-2.19, -0.34; p=0.007)

Table 4. Proportions maintaining at least 5% weight loss at 6 and 12 months

	Proportion losing at least 5% of baseline weight or more – complete cases		Risk ratio of achieving weight loss of 5% of baseline weight or more compared to the Control group – complete cases		Proportion losing at least 5% of baseline weight or more – imputed data		Risk ratio of achieving weight loss of 5% of baseline weight or more compared to the Control group – imputed data	
	6 months	12 months	6 months	12 months	6 months	12 months	6 months	12 months
Control	16/136 (11.8%)	42/227 (18.5%)	1.00	1.00	15.9%	20.8%	1.00	1.00
POWeR+F	59/148 (39.9%)	62/221 (28.1%)	3.42 (2.10, 5.56; p<0.001)	1.46 (1.02, 2.08; p=0.036)	36.8%	29.2%	3.10 (1.85, 5.18; p<0.001)	1.56 (0.96, 2.51; p=0.070)
POWeR+R	55/155 (35.5%)	69/218 (31.7%)	3.02 (1.89, 4.83; p<0.001)	1.67 (1.17, 2.37; p=0.004)	33.7%	32.4%	2.64 (1.60, 4.36; p<0.001)	1.82 (1.21, 2.74; p=0.004)

Table 5. Incremental overall NHS cost per Kg weight lost (ICER) compared with the control group based on the imputed data using repeated measurement

Group vs. group	Mean difference of costs in £(95% CI)	Mean of weight lost (kg) (95% CI)	Incremental cost (£) per weight lost (95% CI)
POWeR+F vs. Control group	23 (-105, 152)	1.49 (0.58, 2.41)	18 (-129, 195)
POWeR+R vs. Control group	-36 (-154, 81)	1.27 (0.34, 2.19)	-25(-268, 157)

Table 6. Additional activities undertaken over 12 months, and patient enablement in managing their weight

	Control (n (%))	Face-to-face (n (%))	Remote (n (%))
Additional activities			
Take part in regular activity long enough to work up a sweat			
- Rarely	50/135 (37.0%)	38/134 (28.4%)	39/146 (26.7%)
- Sometimes	57/135 (42.2%)	69/134 (51.5%)	77/146 (52.7%)
- Often	28/135 (20.7%)	27/134 (20.2%)	30/146 (20.6%)
Take part in another weight loss activity	64/136 (47.1%)	51/137 (37.2%)	40/150 (26.7%)
Of these the reported activities were:			
Weightwatchers/Slimming World (or similar) meetings	23/136 (16.9%)	22/137 (16.1%)	14/150 (9.3%)
Another weight management website	0/135 (0.0%)	4/136 (2.9%)	4/150 (2.7%)
Phone app	13/136 (9.6%)	8/136 (5.9%)	10/149 (6.7%)
Weight loss pills	5/136 (3.7%)	4/137 (2.9%)	2/150 (1.3%)
Health trainer program	4/136 (2.9%)	2/136 (1.5%)	3/148 (2.0%)
Exercise referral scheme	4/136 (2.9%)	7/137 (5.1%)	4/148 (2.7%)
Another weight loss scheme	8/136 (5.9%)	13/136 (9.6%)	8/149 (5.4%)
Any other weight management method	22/97 (22.7%)	13/87 (14.9%)	8/103 (7.8%)
Patient enablement			
Mean Item score at baseline (SD)	3.19 (1.27)	3.42 (1.19)	3.31 (1.26)
Mean Item score at 12 months (SD)	3.23 (1.57)	4.10 (1.28)	3.85 (1.35)
Difference in enablement score compared to control group (95% confidence intervals)		0.70 (0.39, 1.01; p<0.001)	0.54 (0.24, 0.85; p<0.001)

Discussion.

This is one of few studies comparing simple weight management interventions using primary care staff for support to manage obesity. Clinically important weight loss was achieved by some participants in the active control group, and the mean weight reduction at the end of 12 months was not significantly less than the POWeR+ behavioural web-based intervention groups. However in the POWeR+ groups significantly more weight loss occurred averaged over 12 months, by 12 months more participants maintained clinically important weight reduction, and more patients felt enabled to manage their weight. With brief nurse remote support for POWeR+ this was achieved without increasing health service costs.

Strengths and limitations.

The individuals who take part in trials are likely to be a relatively well-motivated group, but this is also the intended target group where intervention is most likely to be helpful. The study was large and pragmatic, mimicking the everyday conditions in primary care settings, which had the disadvantage that the control group were not closely controlled, and so they undertook other activities to lose weight. This is also a strength as estimates are more realistic - since this would happen in practice. Participants with obesity in primary care settings are notoriously difficult to follow-up, but we achieved follow-up of more than 80% of individuals at 12 months. Loss to follow-up was similar between arms, which reduces the impact of missing data. Furthermore, we have reported the primary analysis using the imputed data, which provides more conservative (i.e. smaller) estimates of effectiveness than complete cases. However, in practice multiple imputation modified the estimates only slightly - which suggests that attrition bias was not a major issue. Based on the experience of piloting, where pressure to achieve follow-up of both primary and secondary outcomes resulted in participants dropping out, our effort concentrated on maximising the primary outcome, which resulted in fewer secondary outcomes being available. The fact that we found significant weight loss irrespective of the method of specifying the weight outcome (average reduction over 12 months as specified in the funding application, or clinically important weight loss at 6 or 12 months), and that most secondary outcomes also changed in positive directions albeit mostly not significantly, makes selective reporting and type I error less likely.

Main findings put in context of existing literature.

Our observation of 3% loss in weight in the active control group, and the maintenance of clinically important weight loss in 11.8% and 18.5% of participants at 6 and 12 months respectively, was consistent with our previous findings¹² – i.e. that a brief intervention promoting the use of simple sheets for food swaps and five-a-day fruit and vegetable consumption helps with weight control. Some of the effective weight management in this group may also be due to the motivational effects of regular follow-up weighing by the nurse, and undertaking other activities to help themselves (which about 50% did). In

contrast, fewer individuals offered the POWeR+ interventions undertook other activities, and they felt significantly more enabled to manage their weight.

Systematic reviews of interventions in other settings and primary care suggest that both intensive dietetic behavioural counselling and intensive follow-up are usually necessary to achieve effective weight reduction^{4 7 21}. In contrast, we found that a behavioural web-based intervention such as POWeR+ was effective with just a few brief phone calls and emails plus 6 monthly weighing. The weight loss achieved with POWeR+ compares favourably with other internet-based interventions, which on average²² (albeit with high heterogeneity) have led to only short term weight loss, of less than 1kg weight loss compared to no treatment controls, or less than 2KG if combined with face-to-face support - based on a review of predominantly motivated volunteer samples²². Better weight management results using an internet-based programme (around 5Kg) have only been achieved with much more intensive human support (for example, weekly 20 minute contact for 12 weeks, and then monthly up to 24 month follow-up¹⁰⁹). Encouragingly, the weight loss achieved by POWeR+ was comparable to the best performing interventions^{15 23} evaluated over 12 months in a primary care setting, including those produced by face-to-face commercial programmes. Controlling for deprivation made no difference to the estimates and there was also no interaction with deprivation.

The estimates of resource use suggest that both interventions were not very resource intensive. Considering overall NHS costs, fewer NHS resources were used in the Remote group, mainly due to reduced primary care costs. Given the variability of cost estimates, these results must be treated with some caution, but it seems unlikely that health service costs will be significantly increased with the Remote intervention. We also found that POWeR+ users felt significantly more enabled to manage their condition, so it is plausible that if individuals can be enabled to manage their own condition without needing significant face-to-face contact, this could empower self-management more generally. Previous modelling by NICE demonstrated that cost-effectiveness is very sensitive to whether weight loss is maintained but that at least a 1 kg per head weight loss among overweight or obese adults is likely to be cost effective if is maintained, provided that the cost per person of intervening is less than £100. The current results suggests that irrespective of whether intervention costs or overall costs are used both interventions achieve weight losses at a cost per kg below that required by NICE⁴. The POWeR+ intervention was for 6 months but the number maintaining clinically important weight loss remained steady to 1 year which suggests longer term benefit could be achieved. However, since weight loss may not be maintained after 1 year, future research should assess the extent to which clinically important weight loss can be maintained beyond one year.

Conclusion. A web-based behavioural weight management programme (POWeR+) with brief remote follow-up is effective, helps participants feel more enabled to manage their weight, provides comparable results to the best performing interventions evaluated in primary care settings including commercial programmes, and is likely to be cost-effective.

.Research in context.

Previous evidence. The most recent systematic review published by Hutcheson et al included studies of adults aged ≥ 18 years assessing weight loss or weight maintenance interventions using an e-Health component. Eight databases were searched (The Cochrane Library, MEDLINE/PREMEDLINE, EMBASE, CINAHL, Web of Science, Scopus, PubMed, and PsycINFO) from 1995 to 17 September 2014. The search terms were obesity/ or obesity, abdominal/ or obesity, orbid/Overweight/Adiposity/ obese.mp.ehealth.mp. or telemedicine/ telehealth.mp.Text Messaging/mhealth.mp.Computers, Handheld/ (tablet* and (mac or ipad or android* or microsoft or windows)).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept, rare disease supplementary concept, unique identifier]exp Internet/world wide web.mp.web based.mp. ((web* or remote or online) adj3 deliver*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept, rare disease supplementary concept, unique identifier]website*.mp.online.ab,ti.smart phone*.mp.digital game*.mp.smartphone*.mp.Computer Simulation/ or virtual reality.mp. exp diet/healthy eating.tw.nutrition.tw.physical activity.tw.exp exercise/*motor activity/*Physical Fitness. The quality (risk of bias) for twenty-three (27.4%) of studies were classified as higher quality, 67.9% ($n = 57$) moderate quality and 10.7% ($n = 9$) lower quality.

Meta-analysis demonstrated significantly greater weight loss (kg) in eHealth weight loss interventions compared with minimal interventions (MD -1.40 [$-1.98, -0.82$], $P < 0.001$). However, of the 9 studies, 2 had unusual populations (University staff; lactating women), and the only study to report fewer than 10 contacts by behavioural counsellors documented less than 1.5Kg weight loss and high attrition at 12 months with only 49% of individuals followed-up. Thus there is poor evidence for the effectiveness for internet interventions utilising brief behavioural support in a primary care setting.

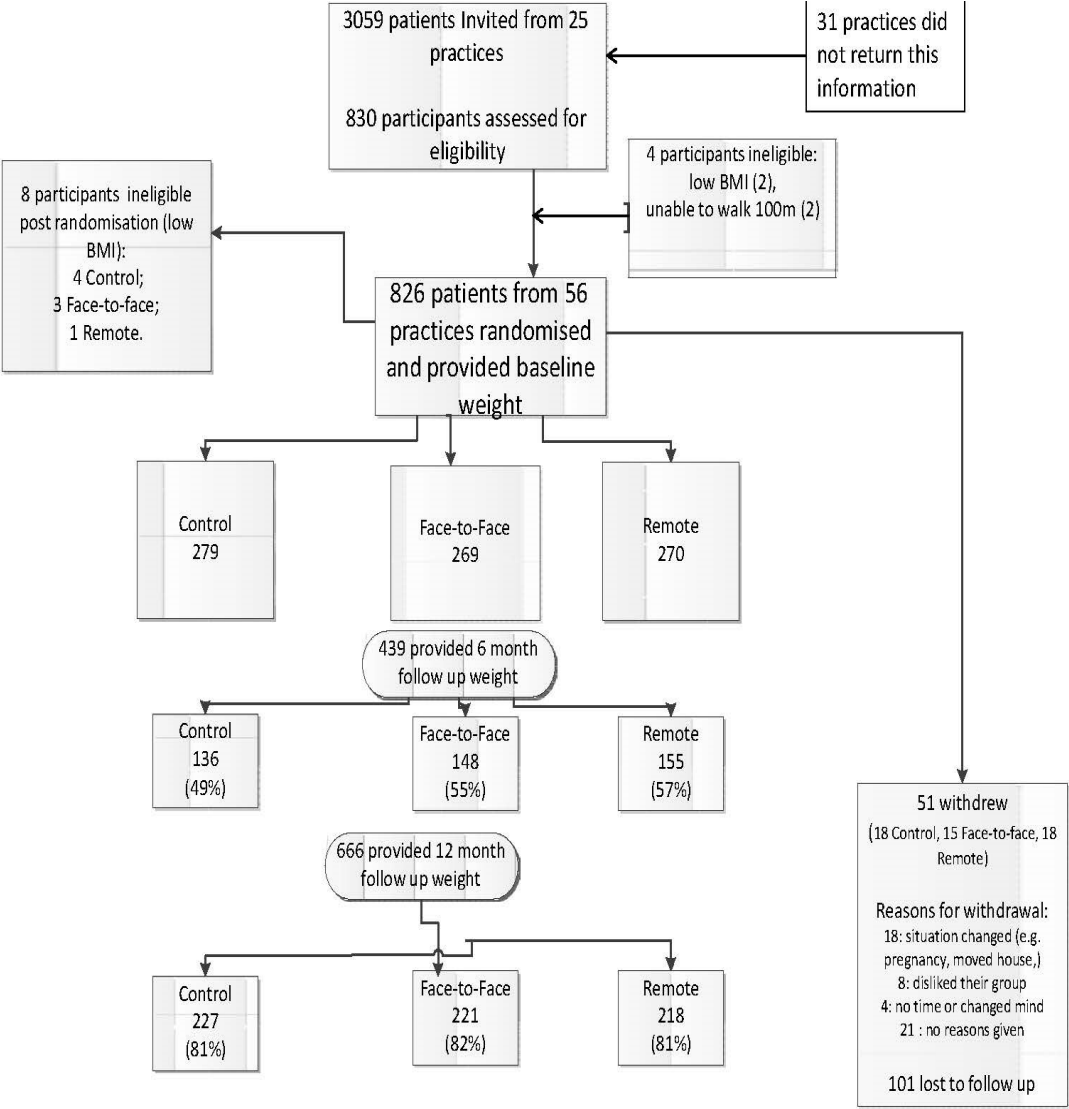
What this study adds. Our results fill this gap by demonstrating that clinically important weight reduction is possible with a web-based behavioural programme lasting 6 months combined with brief remote follow-up (achieving approximately 1.5 Kg more weight loss than an active control intervention and 30% maintaining 5% weight loss by 12 months), with less recourse to other weight loss activities and is likely to be cost-effective.

Implications of all the available evidence. The weight loss achieved by POWeR+ was comparable to the best performing interventions evaluated in a primary care setting over a 12 month period, including those produced by face-to-face commercial programmes.

Implications for practice. The POWeR+ Programme when combined with very brief staff support could be feasibly used in most practices and make a clinically important contribution to the management of obesity.

Future research. Since weight loss may not be maintained after 1 year, future research should assess the extent to which clinically important weight loss can be maintained beyond one year.

Figure 1. CONSORT Diagram



Competing Interests. All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work ; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work. Data sharing: there is no further data available.

The views expressed in this publication are those of the authors and not necessarily those of the HTA, NHS, NIHR or the Department of Health. PL affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained. The corresponding author (PL) has final responsibility for the manuscript.

Contributorship: Paul Little (GP and Professor of Primary Care Research, University of Southampton) had the original idea for the protocol, led protocol development and the funding application, supervised the running of the lead study centre and coordination of centres, contributed to the analysis, led the drafting of the paper. F.D.R. Hobbs (GP and Professor of Primary Care, University of Oxford, and Professorial Fellow at Harris Manchester College) developed the protocol for funding, contributed to management of the study, supervised the Oxford study centre and contributed to the drafting of the paper. Jo Kelly and Emily Smith (senior trial managers, University of Southampton) developed the protocol, provided day to day overall management of the study, coordinated recruitment in the lead study centre and coordination of other centre, and commented on drafts of the paper. Mina Davoudianfar coordinated the Oxford study centre. Julie Hooper provided coordination and data management for the Southampton study centre. Guiqing Yao and Shihua Zhu with Professor James Raftery (Health Economists) developed the protocol for analysis of the notes review data, analysed the resource use data, and contributed to the drafting of the paper. James Raftery contributed to the management of the study, and supervised the analysis of resource use data. Katherine Bradbury, assisted by Stephanie Hughes (Health Psychologists, University of Southampton), contributed to protocol development, were responsible for the day to day development and piloting of the intervention, and commented on drafts of the paper. Michael Moore (GP and Professor in Primary Care, University of Southampton), developed the protocol for funding, contributed to the management of the study, contributed to the analysis and to the drafting of the paper. J David Turner (UEA) helped develop the protocol for funding. Beth Stuart. (Study Statistician, University of Southampton) with Peter Smith (Professor of Statistics, University of Southampton) developed the analysis protocol, performed the quantitative analysis, and contributed to drafting of the paper. Lucy Yardley (Professor of Health Psychology, University of Southampton) developed the protocol and funding application with PL, led the development of the intervention, contributed to daily supervision of website issues, contributed to broader study management, and contributed to drafting the paper. Professors Mike Lean, Barrie Margetts, and Chris Byrne developed the protocol for funding, contributed to management of the study, and contributed to the drafting of the paper.

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Appendix 1

Intervention description: POWeR+

Positive Online Weight Management Plus (POWeR+) is an automated online intervention to support weight management over one year. POWeR+ was developed from the initial 12 session POWeR intervention, which was subject to a feasibility trial²⁴. It was adapted from an earlier version (POWeR) which was extensively trialled and shown to improve weight loss. Development was informed by the Person-Based Approach (PBA)²⁵ which employs an iterative process of in-depth qualitative user testing, and a theoretical basis involving the principles of self-determination theory²⁸ and techniques from cognitive behavioural theory²⁶. The Person-Based Approach was used for development to maximise acceptability, feasibility and engagement^{25 27 28}.

POWeR+ was designed to provide support for sustainable long-term self-management of weight. Patients choose either a low calorie eating plan (a reduction of around 600 calories a day) or a low carbohydrate eating plan (a carbohydrate limit of 50g a day). Users can base their eating plan on a traffic light system that categorises foods into those that could be eaten freely ('green'), in moderation ('orange') or very sparingly ('red'). The low carbohydrate eating plan categorises most vegetables and some fruits as 'green' and only categorises very high sugar and starchy foods as 'red' and is therefore compatible with a sustainable healthy diet. Patients are also encouraged to increase their physical activity levels by choosing either a walking plan (in which case they can request a pedometer) or a self-selected mixture of other physical activities.

POWeR+ focuses principally on fostering users' self-regulation skills for autonomously self-managing their weight, rather than providing detailed dietetic advice. Throughout POWeR+, users are taught active cognitive and behavioural self-regulation techniques ('POWeR tools') to overcome problems such as low motivation, confidence or relapse. Evidence is provided for the effectiveness of these techniques and examples given of how others have successfully used them ('POWeR stories'). POWeR+ emphasises forming healthy eating and physical activity habits that should become non-intrusive and require little effort to sustain. POWeR+ is tailored by gender, using language and 'POWeR stories' designed to appeal to men and women.

The intervention was developed based on behavioural theory and evidence from existing successful interventions, with very extensive iterative qualitative piloting with a wide range of users from the target population to check usability, accessibility and acceptability and to elicit and respond to user views. Further details of the intervention development and early evaluation are given elsewhere^{24 27 29-31}. Aspects of POWeR+ that were modified from the original POWeR intervention included; use of game-based techniques (i.e. sessions grouped into stages that the user advances through), addition of extensive novel content (extra sessions to maintain interest for a longer period), shorter sessions (to enhance engagement), and improvements to usability and navigation.

Participants were encouraged to continue to use the website weekly to track their weight, set and review eating and physical activity goals, and receive personalised advice. After entering their weight and whether they had achieved the goals they had set themselves the previous week, patients received tailored feedback giving encouragement if maintaining weight loss (e.g. reminders of health benefits accrued) and meeting goals. Weight gain and failing to meet goals triggered automated personalised advice such as appropriate goal-setting and planning, boosting motivation, overcoming difficulties, recovering from lapses.

Overview of the 4 stages of POWeR+

Stage 1: Users are tunnelled (i.e. they cannot proceed to a session until they have completed the previous session) through 3 core sessions introducing them to POWeR and guiding them through the process of setting and reviewing weekly goals (see figure 1). There are 3 components to the goal review:

- Recording weight
- Choosing an eating plan from:
 - o A low calorie diet
 - o A low carbohydrate diet
- Choosing a PA plan
 - o Increasing walking using a provided pedometer and recording the weekly step count.
 - o Choosing any other physical activity and setting weekly goals

Participants may opt to change their plans after their weekly goal review at any point during the intervention.

Stage 2: Users have free choice access (i.e. they can access the sessions in any order) of sessions 4-10. Goals can now be reviewed weekly and users can view their progress on a graph. If a user misses a week of goal review, they may still review their goals the following week. After all sessions are completed or a period of 7 weeks has passed since the stage was started, stage 3 sessions become available.

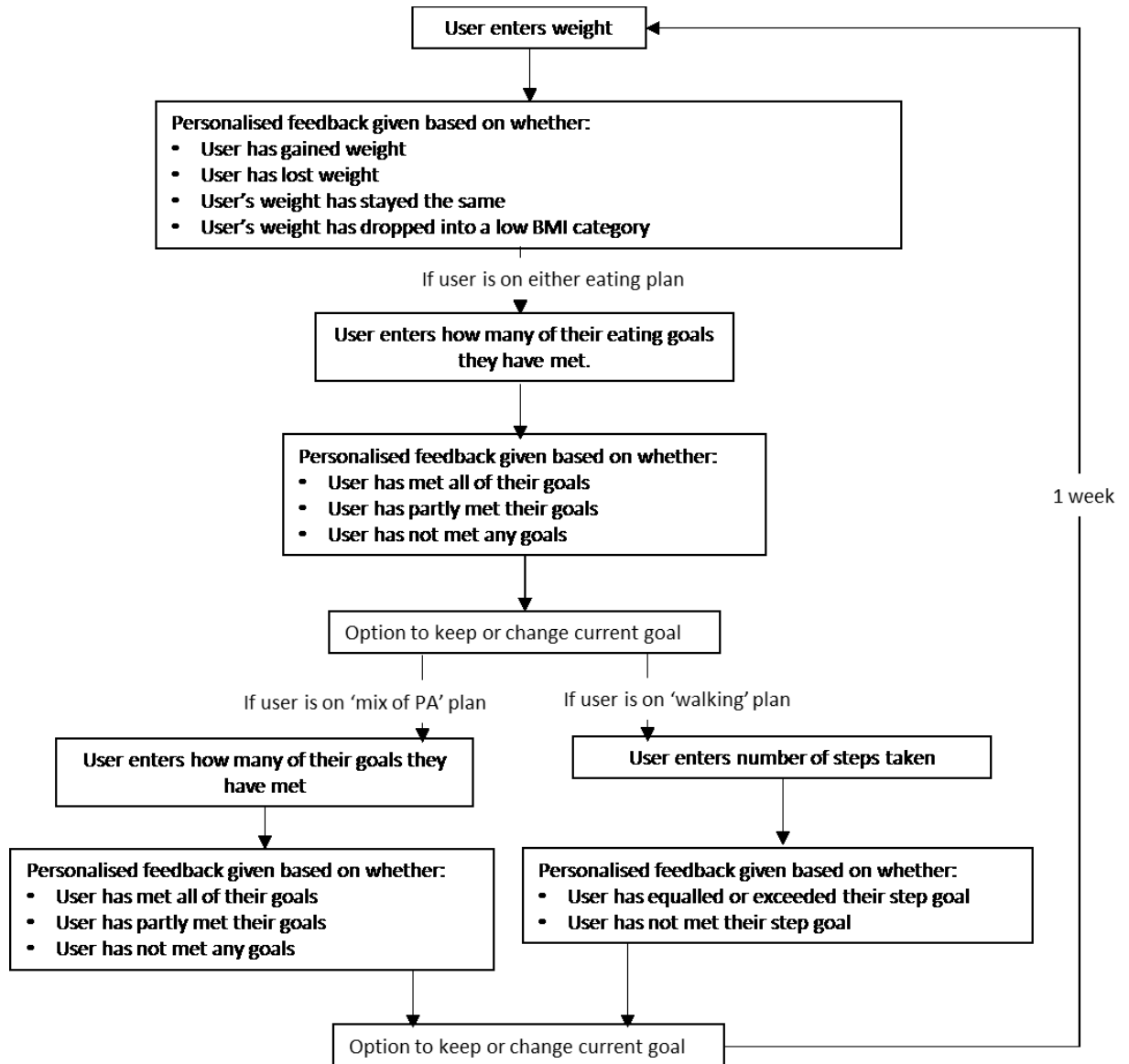
Stage 3: Users have free choice access to sessions 11-17 and continue complete weekly goal reviews. After all sessions are completed or a period of 7 weeks has passed since the stage was started, stage 4 sessions become available.

Stage 4: Users have free choice access to sessions 18 – 25 and continue to complete weekly goal reviews. Throughout the intervention, weekly emails are sent to remind users to complete their goal review. Set periods of inactivity at various points during the intervention also trigger emails prompting users to return to either complete sessions or their goal review.

Overview of POWeR+ stages and session titles

Stage 1 (user is tunnelled through these sessions)	
Session 1 pt 1	Introduction to POWeR
Session 1 pt 2	Introduction to goal setting and weekly weighing
Session 2	Getting support from other people
Session 3	Physical activity
Stage 2 (free choice sessions. These are unlocked once user completes session 3)	
Session 4	Setting the strongest plans – mini session
Session 5	Controlling your cravings
Session 6	Stretching your physical activity
Session 7	Setting up your environment to help you lose weight
Session 8	Dealing with slip ups
Session 9	How to break bad habits – mini session
Session 10	How to develop your new healthy identity – mini session
Stage 3 (free choice sessions unlocked once user completes stage 2 or after 7 weeks)	
Session 11	Eating when times are tough
Session 12	Eating out
Session 13	Being drink aware
Session 14	Take on a physical activity challenge – mini session
Session 15	A quiz to show you which tricky situations you are best at dealing with, and which you still need to work on – mini session
Session 16	Winning against temptations – mini session
Session 17	When losing weight gets hard – mini session
Stage 4 (free choice sessions unlocked once user completes stage 3 or after 7 weeks)	
Session 18	Using mindfulness to help you lose weight
Session 19	Getting support from your family – mini session
Session 20	Have you made your changes into habits? Take this quiz to find out – mini session
Session 21	Make new habits easier, by linking them to things you already do – mini session
Session 22	A quick, easy tool to stop stress spoiling your weight loss – mini session
Session 23	Busy lives
Session 24	Maintaining your weight loss – we recommend you complete this session last
Session 25	Successful celebrations(only available from the ‘tools’ page)

Figure 1: Overview of weekly goal review



Appendix 2.

The costing (summarised in Table 7) comprised two elements: one measuring the intervention cost alone, based on the cost of internet plus that of nurse support. The other was total cost i.e. the cost of the intervention plus differences in cost of NHS services related to obesity. The perspective was that of the NHS and personal social services. The time horizon was 12 months.

The main costs of the intervention were nurse supporting time in terms of face to face consultations, telephone or email contact. The cost of nurse support was based on trial data on the number of contacts by type (face-to-face, telephone and email, all with the practice nurse). Face-to-face contacts linked to the trial interventions were planned to last half as long as normal visits. These were assumed to cost 50% of standard practice nurse consultations¹. The time taken for telephone contacts relative to face to face to visits was based on the split provided for GPs between face to face and other contacts in PSSRU unit costs. The time taken for email contacts was set at 50% that of telephone contacts. These were all costed using national costs per consultation for a practice nurse (PSSRU, 2013/14). The unit costs used in costing the intervention are shown in the table below.

The cost of the intervention comprised the cost of the web site and the support offered to users. The development costs of providing a web intervention that could be used very widely would be spread among thousands of individuals. We estimated the cost of the website at £1 per person using it, mainly due to the cost of providing and maintaining the website. No cost has been applied to those using the site, but not having access to the intervention. Although pedometers were offered to participants in the POWeR+ groups (costing £10), the impact was modest, and since starting the study pedometer apps for mobile phones have become widely available for the target population. Thus we anticipate that in implementing the intervention no offer of pedometers would be made, hence our base case assumption does not allow for the cost of pedometers. Even if we assume that the additional £10 is a necessary part of the intervention this would still leave the intervention costs per Kg lost at well under £100/kg, and so does not alter the inferences.

The cost of the control group with brief verbal intervention and supporting advice sheets was not costed specifically but assumed to be part of primary care consultations. Resource use data were extracted from GP case-notes 12 months after recruitment covering medication, primary care visits, outpatient consultant, A&E attendance and hospital admission. Intervention-specific resource use was recorded by study nurse.

Data collected covered medications plausibly associated with obesity: diabetes, blood pressure, clotting/antiplatelet, diabetes, musculo-skeletal problems (back, hip and knee pain), lipid lowering and weight management. The names of these medications, dosage, and days of use were recorded. Prices were the listed pack price, the cost to the NHS. If a drug was started before the trial starting date and when no ending date was recorded, we assumed that the duration of such use as the length of the trial (12

months). For rest of the medications, if no duration of use was available, the actual and recommended duration the number of packs was estimated from the starting data of the medication. The unit costs of medications were obtained from the British National Formulary (BNF) in 2013-2014 prices (British National Formulary <http://www.bnf.org>). Consultations in primary care, walking in centre, A&E and outpatient attendances were recorded and priced using PSSRU 2013/4 unit costs.

Data on all hospital admissions were also extracted. We used HRG cost per episode for hospitalisation-specific causes of admission 2013/4 (Department of Health (2014) NHS Reference Costs 2013 to 2014. <https://www.gov.uk/government/publications/nhs-reference-costs-2013-to-2014>). Data on these unit costs and those for medications are available on request.

Table 7a Summary of the intervention specific nurse support : mean number of contacts by type

Intervention groups	Contacts	Mean (95% CI)	Mean (95% CI)
		Mean for those using the service	Mean for all
POWeR+ F N=269	face to face	2.33 (2.17, 2.49) n=173	1.5 (1.33, 1.67)
	Email	2.13 (1.91, 2.35) n=116	0.92 (0.76, 1.08)
	Phone	1.82 (1.6, 2.03) n=120	0.81 (0.67, 0.95)
	Total	4.5 (4.25, 4.74) n=193	3.23 (2.93, 3.53)
POWeR+R N=270	face to face	1.56 (1.13, 1.98) n=18	0.1 (0.05, 0.16)
	Email	3.13 (2.94, 3.32) n=173	2 (1.79, 2.22)
	Phone	1.62 (1.47, 1.77) n=124	0.74 (0.63, 0.86)
	Total	4.25 (4.05, 4.46) n=181	2.85 (2.58, 3.13)

Table 7b Mean obesity-related NHS resource use in each group (2013/2014 prices)

Groups		Categories	Means (95% CI) for those using service	Mean for All (95% CI)
Control group N=259	Cost (£)	All costs	428 (320, 537) n=259	428(320, 537)
		Medication	271 (191, 350) n=119	124(85, 164)
		GP consultation	72 (60, 83) n=142	39(32, 47)
		Outpatient attendance	548 (388, 709) n=49	104(64, 143)
		Hospital admission	2569 (1158, 39805) n=11	109(28, 190)
	Number of cases	Medication usage	3.23 (2.84, 3.62) n=119	1.48(1.22, 1.75)
		GP consultation	2.68 (2.33, 3.03) n=142	1.47(1.22, 1.72)
		Outpatient attendance	4.06 (2.87, 5.25) n=49	0.77(0.48, 1.06)
		Hospital admission	1 (1, 1) n=11	0.04(0.02, 0.07)
POWeR+F N=250	Cost (£)	All costs	431 (319, 543) n=250	431(319, 543)
		Medication	191 (150, 232) n=140	107(81, 133)
		GP consultation	83 (67, 97) n=148	49(39, 59)
		Outpatient attendance	534 (373, 695) n=47	100(61, 140)
		Hospital admission	3986 (1840, 6132) n=7	112(18, 205)
		Nurse support	22 (21, 23) n=193	17(15, 18)
	Number of cases	Medication usage	2.84 (2.55, 3.13) n=140	1.59(1.35, 1.83)
		GP consultation	2.74 (2.37, 3.11) n=149	1.63(1.36, 1.91)
		Outpatient attendance	3.96 (2.76, 5.15) n=47	0.74(0.45, 1.03)
		Hospital admission	1.43 (0.7, 2.16) n=7	0.04(0.01, 0.07)
		Nurse support	4.5 (4.25, 4.74) n=193	3.47(3.17, 3.77)
POWeR+R N=244	Cost (£)	All costs	386 (296, 477) n=244	386(296, 477)
		Medication	215 (150, 279) n=122	107(73, 142)
		GP consultation	63 (53, 73) n=126	33(26, 39)
		Outpatient attendance	530 (375, 684) n=52	113(71, 155)
		Hospital admission	2794 (997, 4591) n=6	69(6, 132)
		Nurse support	12 (11, 13) n=181	9(8, 10)
	Number of cases	Medication usage	3.17 (2.8, 3.55) n=122	1.59(1.31, 1.86)
		GP consultation	2.55 (2.2, 2.91) n=127	1.33(1.08, 1.57)
		Outpatient attendance	3.92 (2.78, 5.07) n=52	0.84(0.52, 1.15)
		Hospital admission	1.33 (0.48, 2.19) n=6	0.03(0, 0.06)
		Nurse support	4.25 (4.05, 4.46) n=181	3.16(2.88, 3.43)

Notes: All costs comprise the total of all costs incurred. The main components of all costs were GP consultations, medications, outpatient attendance, hospital admissions and nurse support contacts.

The intervention cost (under “Nurse Support” in Table 7b) was £17 (15 to 18) in the POWER+F group and £9 (8 to 10) in the POWER+R group. Total mean NHS obesity related cost by arm (“All Costs” in Table 7b), including “nurse support” in each intervention arm, was £428 (320 to 537) in the control group, £431 (319 to 543) in the POWeR+ Face-to Face and lower in the POWeR+Remote arm at £386 (296 to 477). If bootstrapping is used these estimates are £424 (338, 515) in the control group, £447 (358, 544) in the POWeR+ Face-to Face and lower in the POWeR+Remote arm at £388 (315, 468), with

difference to the control group for POWeR+ Face-to Face of 23 (-105 to 152) and POWeR+Remote -36 (-154 to 81). These cost differences were not statistically significant.

Cost effectiveness acceptability curves

The cost effectiveness acceptability curves (Figures 2, and 3) for weight loss show the probability of each of the comparisons being cost effective in terms of levels of willingness to pay per kilogram lost. These put the probability of being cost effective at well over 80% for both interventions compared with the control group. There was little difference between the two intervention groups in terms of incremental cost per kg lost.

Figure 2 Cost effectiveness acceptability curve of POWeR+F compared with control group based on weight loss from baseline (kg) over 12 months

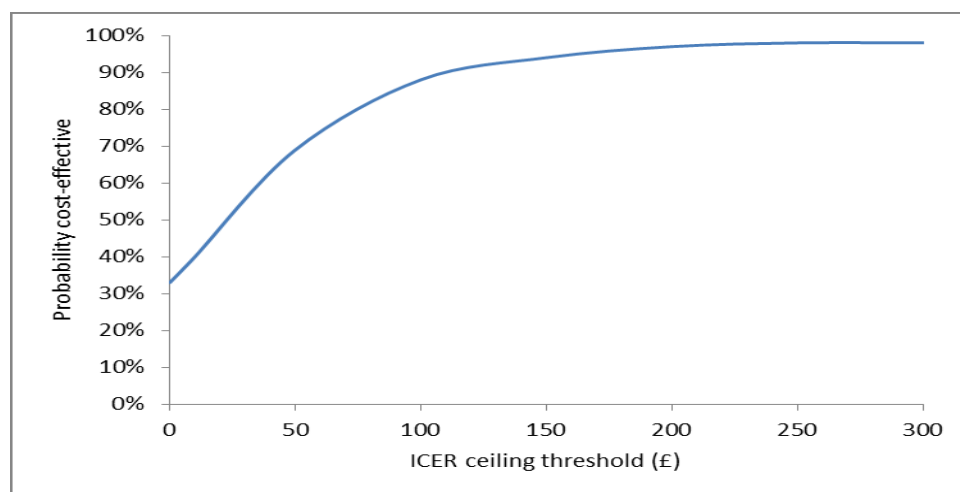
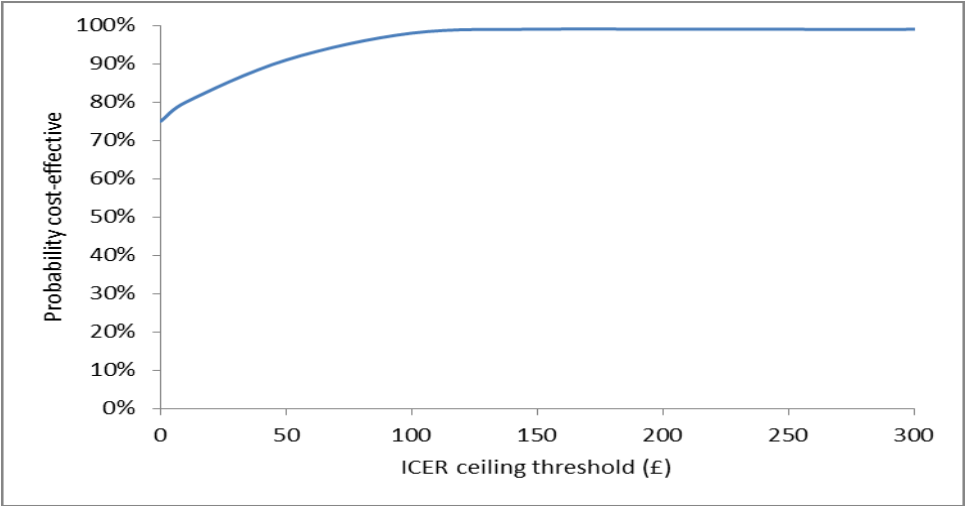


Figure 3 Cost effectiveness acceptability curve of POWeR+R compared with control group based on weight loss from baseline (kg) over 12 months



Appendix 3:

Sub-group analysis

Metabolic syndrome: The interaction term for those having the metabolic syndrome at 6 months was 3.04 (95% CI 0.33, 5.74; $p=0.028$) for the Face-to-face group and 1.26 (95% CI -1.37, 3.88; $p=0.348$) for the Remote group, i.e. the Face-to-face intervention was more effective in those not having the metabolic syndrome, but this was only evident in the short term. At 12 months, the interaction terms were 0.58 (-2.42, 3.57; $p=0.707$) for the Face-to-face group and 0.45 (-2.51, 3.41; $p=0.765$) for the Remote group.

Waist circumference: We originally specified high waist measurements as a possible subgroup but since only 5 of the trial cohort had low waist measurements this was not possible.

Choice of diet: Among participants who initially chose the low carbohydrate diet compared to a low calorie diet: weight reduction was not significantly greater at 6 months (interaction term -0.77 (-2.09, 0.56; $p=0.258$) nor 12 months (-0.46 (-1.95, 0.84; $p=0.489$); there was no differential effect on lipids; and ferritin was slightly higher at 12 months (+24.3, 95% CI 0.90 to 47.61, $p=0.042$).

Analysis using measured weights only:

Table 8. Complete cases—measured weight only

	Mean kg (SD) at 6 months	Mean Kg (SD) at 12 months
Control	101.86 (19.95)	101.02 (18.26)
Face-to-face	98.58 (17.65)	98.19 (16.10)
Remote	97.18 (16.67)	99.02 (18.13)

Table 9. Complete cases— estimated differences in weight (kg) compared to monitoring group based on measured weight only

	Difference compared to the control group		
	6 months	12 months	Over study period (repeated measures)
POWeR+:Face- to-face	-3.20 (-5.00, -1.39; $p=0.001$)	-1.02 (-2.27, 0.22; $p=0.107$)	-1.78 (-2.81, -0.76; $p=0.001$)
POWeR+: Remote	-3.22 (-5.03, -1.41; $p<0.001$)	-0.96 (-2.21, 0.29; $p=0.134$)	-1.60 (-2.63, 0.57; $p=0.002$)

Appendix 4. Other secondary measures

Physical activity: The validated Godin leisure time physical activity questionnaire.

Food and drink consumption: Using validated brief Food Frequency Questionnaires (FFQs) for major food groups and also alcohol

Indices of the metabolic syndrome 3 out of 5 of elevated waist circumference (<94 cm for men, 80 for women), TG ≥ 1.7 mmol/l, reduced HDLcholesterol (<1.00 mmol/L in males <1.3 mmol/l in females) BP (SPB >130 or diastolic >85 , or treatment of high BP) elevated fasting glucose ≥ 5.6 mmol/l. Individuals with the metabolic syndrome are at particular risk. We report the number (%) in each group using a definition of 3 out of 5 of high measurements³⁰

Waist: nurses measured waist midway between the lower ribs and the iliac crests³¹ and height to allow estimation of BMI; fat mass was measured using Tanita scales;

Blood pressure (BP): Measured 3 times (after 5 min) using a validated OMRON;

Serum measures: Liver function tests, serum cholesterol/HDL/LDL/triglyceride (TG) glucose, HbA1c ; also ferritin (important to measure due to reducing cereals (a key source of iron) in the low carbohydrate diet)

EuroQol (EQ-5D): the EuroQol provided a measure of quality of life for economic analysis;

Table 10a. Liver function tests. Crude data: mean (s.d.) (complete cases)

	ALT Units/l (n=329)		AST Units/l (n=303)		GammaGT Units/l (n=319)	
	Baseline	12 months	Baseline	12 months	Baseline	12 months
Control	30.17 (16.62)	30.23 (15.33)	30.99 (14.26)	29.38 (10.96)	39.18 (35.20)	38.65 (31.01)
POWeR:Face-to-face	31.41 (17.48)	27.26 (14.06)	31.80 (13.79)	27.15 (9.36)	43.76 (46.55)	35.40 (26.10)
POWeR:Remote	31.26 (17.57)	27.68 (16.97)	30.73 (13.69)	27.80 (9.27)	38.04 (30.85)	40.19 (40.47)

Table 10b. Liver function tests: estimated differences using multiple imputation compared to control group (95 % confidence intervals)

	Liver function – Difference compared to control group at 12 months		
	ALT Units/l	AST units/l	GammaGT Units/l
POWeR:Face-to-face	-3.01 (-6.59, 0.57; p=0.093)	-2.21 (-4.77, 0.35; p=0.087)	-3.06 (-9.87, 3.74; p=0.356)
POWeR:Remote	-2.72 (-6.08, 0.64; p=0.107)	-2.02 (-4.38, 0.34; p=0.090)	2.03 (-5.24, 9.32; p=0.568)

Table11a. Glucose, HbA1c and Ferritin (mean, s.d.) (complete cases)

	Glucose mmol/l (n=338)		HbA1C mmol/l (n=330)		Ferritin ug/l (n=362)	
	Baseline	12 months	Baseline	12 months	Baseline	12 months
Control	5.68 (1.88)	5.88 (1.94)	40.49 (10.42)	41.09 (28.68)	N/A	95.73 (94.77)
POWeR:Face-to-face	5.91 (2.53)	5.83 (2.67)	42.00 (13.09)	38.78 (11.39)	N/A	95.47 (84.16)
POWeR:Remote	5.64 (1.93)	5.64 (1.99)	40.07 (11.60)	38.74 (12.79)	N/A	103.78 (76.24)

Table11b. Glucose, HbA1c and Ferritin: estimated difference using multiple imputation compared to control group (95 % confidence intervals)

	Difference compared to control group at 12 months		
	Glucose mmol/l	HbA1C mmol/l	Ferritin ug/l
POWeR:Face-to-face	-0.20 (-0.66, 0.26; p=0.375)	-3.15 (-8.01, 1.72; p=0.192)	-4.69 (-23.78, 14.40; p=0.616)
POWeR:Remote	-0.32 (-0.79, 0.15; p=0.176)	-2.96 (-7.74, 1.83; p=0.213)	5.86 (-12.63, 24.36; p=0.516)

Table 12a. Cholesterol means (s.d.) (complete cases)

	Total (n=346) mmol/l		HDL (n=348) mmol/l		LDL (n=218) mmol/l		Triglycerides (n=286) mmol/l	
	Baseline	12 months	Baseline	12 months	Baseline	12 months	Baseline	12 months
Control	5.30 (1.24)	5.05 (1.26)	1.43 (0.37)	1.37 (0.32)	3.12 (1.03)	2.97 (0.98)	1.74 (0.96)	1.72 (0.82)
POWeR:Face- to-face	5.19 (1.19)	5.18 (1.18)	1.40 (0.33)	1.47 (0.35)	3.02 (0.96)	2.94 (0.98)	1.72 (0.85)	1.75 (1.04)
POWeR: Remote	5.35 (1.33)	5.33 (1.20)	1.41 (0.36)	1.50 (0.38)	3.11 (1.05)	3.08 (1.10)	1.89 (1.59)	1.78 (1.49)

Table 12b. Cholesterol: estimated differences using multiple imputation compared with the control group

	Cholesterol – Difference compared to the control group at 12 months			
	Total mmol/l	HDL mmol/l	LDL mmol/l	Triglycerides mmol/l
POWeR:Face- to-face	0.11 (-0.92, 0.31; p=0.270)	0.08 (0.02, 0.15; p=0.010)	0.01 (-0.19, 0.22; p=0.894)	0.03 (-0.28, 0.34; p=0.826)
POWeR: Remote	0.14 (-0.08, 0.35; p=0.204)	0.10 (0.03, 0.17; p=0.006)	0.06 (-0.16, 0.28; p=0.572)	0.01 (-0.30, 0.32; p=0.937)

Table 13a Body fat percentage and blood pressure mean(s.d.) (complete cases)

	Body fat percentage (n=454)		SBP (n=494) mm Hg		DBP (n=494) mm Hg	
	Baseline	12 months	Baseline	12 months	Baseline	12 months
Control	43.59 (7.08)	42.71 (7.20)	133.78 (17.84)	133.11 (18.61)	81.17 (10.64)	79.10 (10.79)
POWeR:Face- to-face	43.86 (8.00)	41.40 (8.81)	132.28 (15.81)	133.31 (15.70)	80.97 (9.37)	79.89 (9.20)
POWeR: Remote	42.18 (7.79)	40.53 (8.42)	134.17 (17.00)	132.11 (17.08)	80.71 (10.00)	78.92 (9.710)

Table 13b Estimated differences in body fat percentage and systolic (SBP) and diastolic (DBP) blood pressure using multiple imputation compared with the control group

	Body fat percentage	Blood Pressure	
		SBP mm Hg	DBP mm Hg
POWeR:Face- to-face	-0.96 (-1.83, -0.08; p=0.033)	0.05 (-2.76, 2.86; p=0.973)	0.67 (-1.12, 2.46; p=0.461)
POWeR: Remote	-0.53 (-1.47, 0.42; p=0.274)	-2.72 (-5.56, 0.12; p=0.061)	0.02 (-1.64, 1.68; p=0.979)

Table 14. Comparison of weights (Kg) according to diet chosen by the participant (complete cases)

	Mean Kg (SD) at baseline (n=510)	Mean KG (SD) at 6 months (n=303)	Mean Kg (SD) at 12 months (n=392)
Low calorie diet	102.68 (17.35)	98.12 (17.00)	99.25 (17.65)
Low carbohydrate diet	102.57 (18.00)	97.30 (17.86)	98.37 (17.46)

Table 15. Physical activity – Godin questionnaire at 12 months(complete cases)

	Median physical activity score (n=348)	Difference compared to control group
Control group	20 (11,33)	
POWeR+F	25 (12,41)	2.49 (-2.72, 7.70; p=0.348)
POWeR+R	21 (13,45)	-0.90 (-5.97, 4.17; p=0.728)

Table 16a Mean portions (s.d.) of foods eaten per day (complete cases)

	Control		Power Face-to-Face		Power Remote	
	Baseline	12 months	Baseline	12 months	Baseline	12 months
Sweets	1.14 (1.33)	0.89 (0.87)	1.39 (1.66)	0.71 (0.98)	1.24 (1.61)	0.86 (1.32)
Cereals	1.92 (1.17)	1.67 (0.98)	2.02 (1.26)	1.45 (0.97)	1.97 (1.43)	1.40 (0.90)
Fatty Foods	2.72 (1.85)	2.15 (1.67)	2.86 (2.01)	2.06 (1.45)	2.65 (1.83)	1.97 (1.32)
Salty snacks	0.33 (0.62)	0.19 (0.31)	0.33 (0.54)	0.16 (0.23)	0.31 (0.54)	0.15 (0.22)
Sweet drinks	0.49 (1.20)	0.22 (0.59)	0.38 (0.88)	0.11 (0.30)	0.48 (1.17)	0.24 (0.63)
Fruit and veg	3.70 (2.28)	4.63 (2.70)	4.02 (2.57)	4.46 (2.55)	3.85 (2.22)	4.63 (2.40)
Low fat dairy	1.29 (1.44)	1.23 (1.36)	1.64 (1.51)	1.45 (1.53)	1.43 (1.64)	1.53 (1.54)
High to low fat ratio	2.66 (8.27)	1.54 (8.00)	1.52 (6.41)	1.43 (5.53)	2.39 (7.74)	1.39 (4.59)

Table 16b Estimated differences in mean (SD) portions of foods eaten per day (imputed data)

	Difference compared to control group at 12 months						
	Sweets	Cereals	Fatty Foods	Salty snacks	Sweet drinks	Fruit and veg	Low fat dairy
Power+F	-0.18 (-0.37, 0.02; p=0.072)	-0.21 (-0.44, 0.02; p=0.072)	-0.06 (-0.40, 0.28; p=0.722)	-0.03 (-0.09, 0.03; p=0.357)	-0.09 (-0.22, 0.04; p=0.165)	-0.04 (-0.67, 0.58; p=0.888)	0.14 (-0.21, 0.48; p=0.432)
Power+R	-0.13 (-0.32, 0.06; p=0.161)	-0.23 (-0.46, 0.01; p=0.057)	-0.19 (-0.52, 0.15; p=0.270)	-0.04 (-0.09, 0.02; p=0.203)	0.02 (-0.10, 0.14; p=0.769)	0.17 (-0.43, 0.76; p=0.570)	0.27 (-0.09, 0.64; p=0.138)

Table 17. Mean EQ5D scores over 12 months in each group based on complete data

Groups	Time	Mean score in EQ5D (SD), n	95%CI for Mean
POWeR+F N=267	Baseline	0.824 (0.169) n=267	(0.804, 0.845)
	months	0.823 (0.207) n=169	(0.791, 0.854)
	12 months	0.82 (0.207) n=139	(0.786, 0.855)
POWeR+R: N=267	Baseline	0.816 (0.212) n=267	(0.759, 0.841)
	6 months	0.822 (0.2337) n=177	(0.764, 0.857)
	Baseline	0.811 (0.253) n=151	(0.742, 0.851)
Control group: N=276	Baseline	0.786 (0.232) n=276	(0.813, 0.814)
	6months	0.799 (0.234) n=168	(0.829, 0.835)

	12 months	0.783 (0.239) n=134	(0.82, 0.824)
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Table 18 EQ5D changes using bootstrap methods in imputed data

	QALYs	Difference (vs. control)
Control	0.791 (0.769, 0.813)	
POWeR+F	0.823 (0.805, 0.841)	0.032 (0.003, 0.059)
POWeR+R	0.809 (0.787, 0.83)	0.017 (-0.014, 0.048)
POWeR+F vs. POWeR+R		0.014 (-0.013, 0.042)
	QALYs adjusted baseline QoL	Difference (vs. control)
Control	0.005 (-0.007, 0.018)	
POWeR+F	-0.002 (-0.013, 0.009)	-0.007 (-0.024, 0.009)
POWeR+R	-0.008 (-0.02, 0.004)	-0.013 (-0.031, 0.004)
POWeR+F vs. POWeR+R		0.006 (-0.01, 0.023)

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